



1 TITLE OF THE INVENTION

2 VEHICLE SURROUNDINGS MONITORING APPARATUS AND TRAVELING CONTROL
3 SYSTEM INCORPORATING THE APPARATUS

4
5 BACKGROUND OF THE INVENTION

6 1. Field of the invention

7 The present invention relates to a vehicle surroundings
8 monitoring apparatus for recognizing traveling circumstances in
9 front of an own vehicle by stereoscopic cameras, monocular cameras,
10 millimeter wave radars, and the like and for accurately estimating
11 traveling paths of an own vehicle and a traveling control system
12 incorporating such a vehicle surroundings monitoring apparatus.

13 2. Discussion of related arts

14 In recent years, such a traveling control system as
15 detecting traveling circumstances in front of an own vehicle by a
16 camera and the like mounted on a vehicle, estimating traveling paths
17 of the own vehicle from the traveling circumstances data, detecting
18 a preceding vehicle traveling ahead of the own vehicle and making
19 a follow-up control of the preceding vehicle or an intervehicle
20 distance control between the own vehicle and the preceding vehicle,
21 has been put into practical use.

22 For example, Japanese Patent Application Laid-open No.
23 Toku-Kai-Hei 9-91598 discloses a traveling control system in which

1 a traveling path of an own vehicle is estimated from traveling
2 conditions such as yaw rate and other data and a nearest obstacle
3 on the traveling path is detected as a preceding vehicle to be monitored.
4 Further, in the traveling control system, when the preceding vehicle
5 goes out of the traveling path of the own vehicle, the monitoring
6 of the preceding vehicle is released.

7 However, the prior technology in which a traveling path
8 of an own vehicle (hereinafter referred to just as own traveling
9 path) is estimated and a preceding vehicle is caught based on the
10 own traveling path, has a defect that if the estimation of the own
11 traveling path is inaccurate, the capture of the preceding vehicle
12 itself loses reliability and as a result a desired traveling control
13 can not be realized.

14 15 SUMMARY OF THE INVENTION

16 It is an object of the present invention to provide a
17 vehicle surroundings monitoring apparatus capable of stably
18 estimating an own traveling path with high precision and to provide
19 a traveling control system incorporating such a vehicle surroundings
20 monitoring apparatus.

21 According to the present invention, a vehicle surroundings
22 monitoring apparatus inputs images taken by a stereoscopic camera,
23 vehicle speeds, ~~sterring~~ steering wheel rotation angles, yaw rates

1 and ON-OFF signals of a turn signal switch. An own traveling path
2 C is calculated from an own traveling path A obtained from lane markers
3 and side walls and an own traveling path B obtained from yaw rates
4 of the own vehicle. Further, a new own traveling path E is calculated
5 from the own traveling path C and a trace of a preceding vehicle
6 | in case where there is no possibility of ~~evacuation~~a lane change
7 of the preceding vehicle and the turn signal switch is turned off
8 and the absolute value of the steering wheel rotation angle is smaller
9 than a specified value and a present own traveling path is calculated
10 from the own traveling path E and the previous own traveling path.
11 In other cases, the present own traveling path is calculated from
12 the own traveling path C and the previous own traveling path.

13

14 BRIEF DESCRIPTION OF THE DRAWINGS

15 Fig. 1 is a schematic diagram showing a traveling control
16 system incorporating a vehicle surroundings monitoring apparatus
17 according to the present invention;

18 Fig. 2 is a flowchart showing a routine for monitoring
19 surroundings of a vehicle;

20 Fig. 3 is a flowchart showing a routine for estimating
21 a traveling path of an own vehicle;

22 Fig. 4 is a flowchart showing a routine for judging the
23 | possibility of ~~evacuation~~a lane change of a preceding vehicle using

1 a traveling path C of an own vehicle;

2 Fig. 5a is an explanatory diagram showing a process of
3 producing a new traveling path C of an own vehicle from the traveling
4 path A and the traveling path B;

5 Fig. 5b is an explanatory diagram showing a process of
6 producing the new traveling path C when the traveling path A is
7 erroneously recognized;

8 Fig. 5c is an explanatory diagram showing a process of
9 calculating a new traveling path E from the traveling path C and
10 the traveling path D (traveling path of a preceding vehicle); and

11 Fig. 6 is an explanatory diagram showing a process for
12 establishing a judging counter.

13

14 DESCRIPTION OF THE PREFERRED EMBODIMENT

15 Referring now to Fig. 1, reference numeral 1 denotes a
16 vehicle (own vehicle) on which an intervehicle distance automatically
17 adjusting system (Adaptive Cruise Control: ACC) 2 is mounted. The
18 ACC system 2 is constituted by a traveling control unit 3, a
19 stereoscopic camera 4 and a vehicle surroundings monitoring apparatus
20 5. When the ACC system is set to a constant speed control mode, the
21 vehicle travels at a speed established by a vehicle driver and when
22 the system is set to a follow-up traveling control mode, the vehicle
23 travels at a speed targeted to the speed of a preceding vehicle with

1 a constant intervehicle distance to the preceding vehicle maintained.

2 The stereoscopic camera 4 constituting vehicle forward
3 information detecting means is composed of a pair (left and right)
4 of CCD cameras using a solid-state image component such as Charge
5 Coupled Device and the left and right cameras are transversely mounted
6 on a front ceiling of a passenger compartment at a specified interval
7 of distance, respectively. The respective cameras take picture images
8 of an outside object from different view points and input the picture
9 images to the vehicle surroundings monitoring apparatus 5.

10 Further, the vehicle 1 has a vehicle speed sensor 6
11 for detecting a vehicle speed and the detected vehicle speed is
12 inputted to the traveling control unit 3 and the vehicle surroundings
13 monitoring apparatus 5, respectively. Further, the vehicle 1 has
14 a steering angle sensor 7 for detecting a steering angle and a yaw
15 rate sensor 8 for detecting a yaw rate and the detected steering
16 angle and yaw rate signals are inputted to the vehicle surroundings
17 monitoring apparatus 5. Further, a signal from a turn signal switch
18 9 is inputted to the vehicle surroundings monitoring apparatus 5.
19 These sensors 6, 7, 8 and the switch 9 act as own vehicle traveling
20 conditions detecting means.

21 The vehicle surroundings monitoring apparatus 5 inputs
22 respective signals indicative of picture images from the stereoscopic
23 camera 4, vehicle speeds, steering angle, yaw rate and turn signal

1 and detects frontal information about solid objects, side walls and
2 lane markers in front of the vehicle 1 based on the picture images
3 inputted from the stereoscopic camera 4. Then, the apparatus
4 estimates several traveling paths of the own vehicle 1 from the frontal
5 information and traveling conditions of the own vehicle 1 according
6 to the flowchart which will be described hereinafter and estimates
7 a final traveling path of the own vehicle 1 from those traveling
8 paths. Further, the apparatus establishes a traveling region A
9 corresponding to a detected solid object
10 based on the final traveling path. Further, the apparatus establishes
11 a traveling region B corresponding to the solid object based on at
12 least either of the traveling region A and the traveling road
13 information and judges whether the solid object is a preceding vehicle,
14 a tentative preceding vehicle or others according to the state of
15 existence of the solid object in the traveling regions A and B. As
16 a result of the judgment, a preceding vehicle in front of the own
17 vehicle 1 is extracted and the result is outputted to the traveling
18 control unit 3. The vehicle surroundings monitoring apparatus 5
19 includes frontal information detecting means, first own traveling
20 path calculating means, second own traveling path calculating means,
21 third own traveling path calculating means and final own traveling
22 path calculating means.

23 Describing the process of estimating the own traveling

1 path in brief, a new own traveling path C is calculated from the
2 own traveling path A (first own traveling path) obtained based on
3 lane markers and side walls and the own traveling path B (second
4 own traveling path) obtained based on yaw rates of the own vehicle.
5 | Then, the possibility of ~~evaeuation~~a lane change of the preceding
6 vehicle is judged from the relationship between the own traveling
7 path C, the preceding vehicle and the solid object in the vicinity
8 of the preceding vehicle. In case where there is no possibility of
9 | ~~evaeuation~~a lane change of the preceding vehicle, the turn signal
10 switch is turned off, and the absolute value of the steering wheel
11 rotation angle is smaller than a specified value, a new own traveling
12 path E is calculated from the own traveling path C and the locus
13 of the preceding vehicle and a present own traveling path is calculated
14 from the own traveling path E and the previous own traveling path.
15 On the other hand, in case where the conditions described above are
16 not satisfied, a present own traveling path is calculated from the
17 own traveling path C and the previous own traveling path. The vehicle
18 surroundings monitoring apparatus 5 comprises forward information
19 detecting means, preceding vehicle recognizing means, own traveling
20 | path estimating means, first ~~evaeuation~~a lane change possibility
21 | judging means and second ~~evaeuation~~a lane change possibility judging
22 means.

23 Describing the processing of images from the stereoscopic

1 camera 4 in the vehicle surroundings monitoring apparatus 5, with
2 respect to a pair of stereoscopic images taken by the stereoscopic
3 CCD camera 4, distance information over the entire image is obtained
4 from the deviation amount between corresponding positions according
5 | to the principle of ~~trianguration~~triangulation and a distance image
6 representing three-dimensional distance distribution is formed
7 based on the distance information. Then, lane marker data, side wall
8 data such as guardrails, curbs and side walls arranged along the
9 road and solid object data such as vehicles and the like, are extracted
10 by means of the known grouping process and the like by comparing
11 the distance image with the three-dimensional road profile data,
12 side wall data, solid object data and the like stored beforehand.
13 Thus extracted lane marker data, side wall data and solid object
14 data are denoted by different numbers respectively. Further, the
15 solid object data are classified into three kinds of objects, a
16 backward moving object moving toward the own vehicle 1, a still object
17 in standstill and a forward moving object moving in the same direction
18 as the own vehicle 1 based on the relationship between the relative
19 displacement of the distance from the own vehicle and the vehicle
20 speed of the own vehicle 1 and the respective solid object data are
21 outputted.

22 The traveling control unit 3 is equipped with a function
23 of a constant speed traveling control for maintaining the vehicle

1 speed at a value inputted by the vehicle driver and a function of
2 a follow-up traveling control for following up the preceding vehicle
3 in a condition to keep the intervehicle distance between the own
4 vehicle 1 and the preceding vehicle constant. The traveling control
5 unit 3 is connected with a constant speed traveling switch 10
6 constituted by a plurality of switches operated by a constant speed
7 traveling selector lever provided on the side surface of a steering
8 column, the vehicle surroundings monitoring apparatus 5, the vehicle
9 speed sensor 6 and the like.

10 The constant speed traveling switch 10 is constituted by
11 a speed setting switch for setting a target vehicle speed at the
12 constant speed traveling mode, a coast switch for changing the target
13 vehicle speed in a descending direction and a resume switch for
14 changing the target vehicle speed in an ascending direction. Further,
15 a main switch (not shown) for turning the traveling control on or
16 off is disposed in the vicinity of the constant speed traveling
17 selector lever.

18 When the driver turns a main switch (not shown) on and
19 sets a desired vehicle speed by operating the constant speed traveling
20 selector lever, a signal indicative of the desired vehicle speed
21 inputs from the constant speed traveling switch 10 to the traveling
22 control unit 3 and a throttle valve 12 driven by a throttle actuator
23 11 makes a feed-back control so as to converge the vehicle speed

1 detected by the vehicle speed sensor 6 to the established vehicle
2 speed. As a result, the own vehicle 1 can travel at a constant speed
3 automatically.

4 Further, when the traveling control unit 3 makes a constant
5 traveling control, supposing a case where the vehicle surroundings
6 monitoring apparatus 5 recognizes a preceding vehicle, which is
7 traveling at a lower speed than the established vehicle speed, the
8 traveling control unit 3 automatically changes over to a follow-up
9 traveling control mode in which the own vehicle travels in a condition
10 retaining at a constant intervehicle distance.

11 When the constant speed traveling control mode is
12 transferred to the follow-up traveling control mode, a target value
13 of an appropriate intervehicle distance between the own vehicle 1
14 and the preceding vehicle is established based on the intervehicle
15 distance obtained from the vehicle surroundings monitoring apparatus
16 5, the vehicle speed of the own vehicle 1 detected by the vehicle
17 speed sensor 6 and the vehicle speed of the preceding vehicle obtained
18 from the intervehicle distance and the vehicle speed of the own vehicle
19 1. Further, the traveling control unit 3 outputs a drive signal to
20 the throttle actuator 11 and makes a feed-back control of the opening
21 angle of the throttle valve 12 so that the intervehicle distance
22 agrees with the target value and controls the own vehicle 1 in a
23 condition following up the preceding vehicle with the intervehicle

1 distance retained.

2 Next, a vehicle surroundings monitoring program of the
3 vehicle surroundings monitoring apparatus 5 will be described by
4 referring to a flowchart shown in Fig. 2.

5 In this embodiment, the coordinate system of the
6 three-dimensional real space is transferred to a coordinate system
7 fixed to the own vehicle. That is, the coordinate system is composed
8 of X coordinate extending in a widthwise direction of the own vehicle,
9 Y coordinate extending in a vertical direction of the own vehicle,
10 Z coordinate extending in a lengthwise direction of the own vehicle
11 and an origin of the coordinate placed on the road surface directly
12 underneath the central point of two CCD cameras. The positive sides
13 of X, Y and Z coordinates are established in a right direction, in
14 an upward direction and in a forward direction, respectively.

15 The routine shown in Fig. 2 is energized every 50
16 milliseconds. First at a step (hereinafter abbreviated as S) 101,
17 solid object data, side wall data including guardrails, curbs
18 provided along the road and lane marker data are recognized based
19 on images taken by the stereoscopic camera 4. Further, with respect
20 to the solid object data, they are classified into three kinds of
21 objects, backward moving objects, still objects and forward moving
22 objects as described above.

23 Next, the program goes to S102 where the traveling path

1 of the own vehicle is estimated according to a flowchart which will
2 be described hereinafter shown in Fig. 3. First, at S201, the presently
3 obtained own traveling path $Xpr(n)[i]$ is stored as a previous own
4 traveling path $Xpr(n-1)[i]$. $[I]$ denotes node numbers (segment
5 numbers) attached to the own traveling path extending forward from
6 the own vehicle 1. In this embodiment, the own traveling path has
7 24 segments in a forward direction and is composed of a plurality
8 of straight lines connected with each other. Accordingly, Z
9 coordinate at the segment i is established as follows.

10 Z coordinate at segment $i = 10.24$ meters
11 $+ i \cdot 4.096$ meters ($I = 0$ to 23)

12 Then, the program goes to S202 where an own traveling A
13 ($Xpra[i]$, $i = 0$ to 23) is calculated according to the following method
14 A or B.

15 **Method A: Estimation of traveling path based on lane markers**

16 In case where both or either of left and right lane markers
17 data are obtained and the profile of the lane on which the own vehicle
18 1 travels can be estimated from these lane markers data, the traveling
19 path of the own vehicle is formed in parallel with the lane markers
20 in consideration of the width of the own vehicle 1 and the position
21 of the own vehicle 1 in the present lane.

22 **Method B: Estimation of traveling path based on side wall data**

23 In case where both or either of left and right side walls

1 data are obtained and the profile of the lane on which the own vehicle
2 1 travels can be estimated from these side walls data, the traveling
3 path of the own vehicle is formed in parallel with the side walls
4 in consideration of the width of the own vehicle 1 and the position
5 of the own vehicle 1 in the present lane.

6 In case where the own traveling path A cannot be established
7 according to any of the methods A, B mentioned above, it is calculated
8 according to the following methods C or D.

9 **Method C: Estimation of traveling path based on a trace of the**
10 **preceding vehicle**

11 The own traveling path is estimated based on the past
12 traveling trace extracted from the solid object data of the preceding
13 vehicle.

14 **Method D: Estimation of path based on trace of the own vehicle**

15 The own traveling path is estimated based on the traveling
16 conditions such as yaw rate γ , vehicle speed V and steering wheel
17 rotation angle θ_H of the own vehicle 1.

18 After that, the program goes to S203 in which an own
19 traveling path B ($X_{prb}[I]$, $I = 0$ to 23) is calculated based on the
20 yaw rate γ according to the following processes.

21
$$X_{prb}[i] = \gamma \cdot Z^2 + 10240 \text{ (millimeters)}$$

22
$$Z = 4096 \cdot i + 10240 \text{ (millimeters)}$$

23 Thus obtained own traveling path B ($X_{prb}[i]$) is corrected

1 as follows by the state of the steering wheel rotation angle θ_H ,
2 that is, by respective states, during traveling straightforwardly,
3 during turning a curve and during returning the steering wheel to
4 straight.

$$5 \quad Xprb[i] = Xprb[i] \cdot \alpha$$

6 where α is a correction coefficient.

7 The correction coefficient α is established to a value
8 ($\neq 0$) from 0 to 1.0. When the vehicle travels straight or when the
9 vehicle transfers from curve to straight, the correction coefficient
10 α is established to a small value so as to reduce the curvature
11 of the traveling path. When the vehicle turns a curve, the correction
12 coefficient α is established to 1.0 so as to employ the curvature
13 derived from the yaw rate γ as it is.

14 Then, the program goes to S204 where an own traveling path
15 C ($Xprc[i]$, $i = 0$ to 23) is calculated based on the own traveling
16 path A ($Xpra[i]$, $i = 0$ to 23) and the own traveling path B ($Xprb[i]$,
17 $i = 0$ to 23) as shown in Fig. 5a.

$$18 \quad Xprc[i] = (Xpra[i] \cdot \lambda + Xprb[i] \cdot \mu) / (\lambda + \mu)$$

19 where λ and μ are values varying according to the result of
20 recognition of circumstances such as road widths.

21 Thus, in case where the accuracy of the own traveling path
22 A ($Xpra[i]$, $i = 0$ to 23) is exacerbated by erroneous recognition
23 of lane markers or side walls as shown in Fig. 5b, for example, the

1 recognition accuracy of the own traveling path can be prevented from
2 going down by primarily using the own traveling path B ($X_{prb}[i]$,
3 $i = 0$ to 23) by means of establishing μ to a larger value than λ .

4 Then, the program goes to S205 in which it is judged whether
5 or not a preceding vehicle is detected and if detected, the program
6 goes to S206 where the segment kpo on Z coordinate of the preceding
7 vehicle is established as follows:

8
$$Kpo = (Z \text{ coordinate of preceding vehicle} - 10.24) / 4.096$$

9 Then, the program goes to S207 in which the possibility
10 of ~~evacuation~~ a lane change of the preceding vehicle is judged using
11 the own traveling path C ($X_{prc}[i]$, $i = 0$ to 23) calculated at S204,
12 according to a flowchart shown in Fig. 4.

13 In this routine, first, at S301, it is judged whether or
14 not a preceding vehicle exists. If there is no preceding, the program
15 goes to S302 wherein a judging counter TIME is cleared ($TIME = 0$)
16 and then goes to S303 wherein it is judged that there is no preceding
17 vehicle and such a signal is outputted, leaving the routine. In this
18 embodiment, the signal is the same as a signal indicating that there
19 is a possibility of ~~evacuation~~ a lane change of the preceding vehicle.
20 Further, the aforesaid judging counter TIME is for expressing the
21 possibility of ~~evacuation~~ a lane change of the preceding vehicle
22 numerically.

23 On the other hand, in case where it is judged at S301 that

1 there is a preceding vehicle, the program goes to S304 where the
2 absolute value CAL of the difference between X coordinate kpx of
3 the preceding vehicle and X coordinate of the own traveling path
4 C (Xprc[i], i = 0 to 23) on Z coordinate of the preceding vehicle,
5 is calculated ($CAL = |kpx - xpx|$).

6 The processes from S305 to S311 will be described by
7 reference to Fig. 6.

8 First, at S305, it is judged whether or not the segment
9 kpo of Z coordinate of the preceding vehicle is larger than 17. that
10 is, the division is more than 80 meters ahead. If kpo is larger than
11 17, the program goes to S306 in which the judging counter TIME is
12 cleared (TIME = 0) and then goes to S307 a signal indicative of no
13 possibility of ~~evacuation~~ lane change of the preceding vehicle is
14 outputted, leaving the routine.

15 Further, in case where it is judged at S305 that the segment
16 kpo of Z coordinate of the preceding vehicle is smaller than 80 meters,
17 the program goes to S308 in which the judgment counter TIME is
18 initialized according to the position of the preceding vehicle as
19 follows (first ~~evacuation~~ lane change possibility judging means):

20 **A. In case where CAL is smaller than 500 millimeters, that is,**
21 the preceding vehicle is in the vicinity of the traveling path of
22 the own vehicle (region 1 of Fig. 6),

23 TIME = 0

1 B. In case where CAL is larger than 500 millimeters, that is, the
2 preceding vehicle is regarded as traveling apart from the traveling
3 path of the own vehicle

4 (1) In case where the segment kpo of Z coordinate of the
5 preceding vehicle is smaller than 80 meters and larger than 50 meters:

6 In case of $2000 \leq \text{CAL} \leq 3000$ millimeters (region II of Fig,
7 6)

8 $\text{TIME} = \text{TIME} + 5$

9 In case of other than above (particularly, outside of the
10 region II, note that the preceding vehicle travels around
11 curves)

12 $\text{TIME} = \text{TIME} - 5$

13 (2) In case where the segment kpo of Z coordinate of the
14 preceding vehicle is smaller than 50 meters and larger than 30 meters:

15 In case of $1500 \leq \text{CAL} \leq 2500$ millimeters (region III of Fig.
16 6)

17 $\text{TIME} = \text{TIME} + 10$

18 In case of other than above (particularly, outside of the
19 region III, note that the preceding vehicle travels around
20 curves)

21 $\text{TIME} = \text{TIME} - 10$

22 (3) In case where the division of kpo of Z coordinate of the
23 preceding vehicle is smaller than 30 meters:

1 In case of $CAL \geq 1000$ millimeters (region IV of Fig. 6)

2 $TIME = TIME + 30$

3 In case other than above

4 $TIME = TIME - 10$

5 Then, the program goes to S309 wherein the judging counter

6 TIME is established by the solid object other than the preceding

7 vehicle (~~second evaluation~~lane change possibility judging means).

8 For example, in case where a forward traveling solid object enters

9 a traveling region $kpo \pm 1$, the judging counter TIME initialized

10 by S308 is additionally initialized as follows:

11 $TIME = TIME + 10$

12 Then, the program goes to S310 in which it is judged whether

13 or not TIME is larger than a threshold value (for example 100). If

14 TIME is smaller than 100, the program goes to S307 where after a

15 signal indicative of no possibility of ~~evaluation~~lane change of

16 the preceding vehicle is outputted, the program leaves the routine.

17 If TIME is larger than 100, the program goes to S311 where a signal

18 indicative of the possibility of ~~evaluation~~lane change of the

19 preceding vehicle is outputted and leaves the routine. Thus, since

20 the judgment of ~~evaluation~~lane change of the preceding vehicle

21 is made by the own traveling path C ($Xprc[i]$, $i = 0$ to 23) and the

22 position where the preceding vehicle exists, even when no lane markers

23 are seen, an accurate judgment of ~~evaluation~~lane change of the

1 preceding vehicle is available. Further, the accurate judgment of
2 ~~evaeuationa~~ lane change of the preceding vehicle can prevent the
3 ACC system from following up the preceding vehicle hazardously.

4 Since the introduction of this ~~evaeuation~~ lane change
5 judgment process enables an accurate judgment of the possibility
6 of ~~evaeuationa~~ lane change of the preceding vehicle as a monitoring
7 object based on information of the position of the preceding vehicle,
8 the traveling path of the own vehicle and the objects in the
9 neighborhood of the preceding vehicle, not only the preceding vehicle
10 can be continued to be caught as a monitoring object, but also every
11 behavior of the preceding vehicle including the change of the
12 preceding vehicle from one to another can be detected with quick
13 responsibility and accuracy. As a result, the traveling control can
14 be executed stably in a manner similar to driver's driving senses.

15 Thus, after the judging processes of the possibility of
16 ~~evaeuationa~~ lane change of the preceding vehicle are executed using
17 the own traveling path C (Xprc[i], i = 0 to 23) at S207, the program
18 goes to S208 where it is judged from the result of the judgment at
19 S207 whether or not there is a possibility of ~~evaeuationa~~ lane change
20 of the preceding vehicle.

21 If it is judged that there is no possibility of ~~evaeuationa~~ lane change
22 of the preceding vehicle, the program goes to S209 wherein
23 it is judged whether or not the turn signal switch 9 of the own vehicle

1 is turned on. If the turn signal switch 9 is turned off, the program
2 goes to S210 in which it is judged whether or not the absolute value
3 of the steering wheel rotation angle is larger than a specified value,
4 for example 90 degrees. If it is smaller than the specified value,
5 the program goes to S211 where a new own traveling path E ($X_{pre}[i]$,
6 $i = 0$ to 23) is based on the own traveling path C ($X_{prc}[i]$, $i = 0$
7 to 23) and the own traveling path D ($X_{pre}[i]$, $i = 0$ to 23) according
8 to the following formula:

$$9 \quad X_{pre}[i] = X_{prc}[i]$$

10 where $i = 0$ to $(kpo - 2)$, $(kpo + 1)$ to 23

$$11 \quad X_{pre}[i] = (X_{prc}[I] + xpo \cdot \kappa) / (1.0 + \kappa)$$

12 where $i = kpo - 1, kpo$

13 In this embodiment, the own traveling path D is expressed only by
14 X coordinate xpo at the division kpo of Z coordinate of the preceding
15 vehicle. Further, κ is a variable varying according to the
16 recognition of circumstances. When the recognition of circumstances
17 is inferior, κ is established to a large value. That is, in the
18 process of S211, as shown in Fig. 5c, taking the case where the
19 preceding vehicle changes the lane into consideration, only the
20 neighborhood of the preceding vehicle is corrected with respect to
21 the preceding vehicle so that the ACC system 2 operates with accuracy.

22 Then, the program goes to S212 wherein the present own
23 path ($X_{prc}[i]$, $i = 0$ to 23) is calculated from the own traveling

1 path E (Xpre[i], i = 0 to 23) newly calculated presently and the
2 own traveling path (Xpr(n-1)[i], i = 0 to 23) calculated in the previous
3 cycle and stored at S201 as follows:

$$4 \quad Xpr(n)[i] = Xpr(n-1)[i] \cdot \phi - Xpre[i] \cdot (1.0 - \phi)$$

5 where ϕ is a value established according to traveling conditions
6 of the own vehicle. For example, when the vehicle transfers from
7 curved road to straight road, ϕ is established to a small value
8 so as to impose more weight on the own traveling path E (Xpre[i],
9 i = 0 to 23) calculated newly, presently and otherwise ϕ is
10 established to a large value so as to impose more weight on the own
11 traveling path (Xpr(n-1)[i], i = 0 to 23) calculated in the previous
12 cycle. As a result, the response in accordance with the traveling
13 conditions can be obtained.

14 On the other hand, in case where it is judged at S205 that
15 there is no preceding vehicle, or in case where it is judged at S208
16 that there is a possibility of ~~evacuation~~ a lane change, the program
17 goes to S213. Similarly, in case where it is judged at S209 that
18 the turn signal switch 9 is turned on, or in case where it is judged
19 at S210 that the absolute value of the steering wheel rotation angle
20 is larger than a specified value, the program goes to S213.

21 At S213, the present own traveling path (Xpr(n)[i], i =
22 0 to 23) is calculated from the own traveling path C (Xprc[i], i
23 = 0 to 23) calculated at S204 and the previous own traveling path

1 (Xpr(n-1)[i], i = 0 to 23) stored at S201 in the following manner:

2
$$Xpr(n)[i] = Xpr(n-1)[i] \cdot \phi - Xprc[i] \cdot (1.0 - \phi)$$

3 After the own traveling path is estimated, the program
4 goes to S103 where the preceding vehicle is extracted, leaving the
5 routine. The extraction of the preceding vehicle is performed as
6 follows:

7 First, the traveling region A is established based on the
8 traveling path of the own vehicle according to the solid object.
9 Further, the traveling region B is established based on at least
10 either of the traveling region A and road information (road profile
11 estimated from lane markers and side walls). Then, if the detected
12 solid object exists in the traveling region A and if the duration
13 for which the solid object stays in either of the traveling regions
14 A and B, is larger than a specified time and if the solid object
15 is a forward moving object and if the object is nearest one to the
16 own traveling vehicle 1, the solid object is regarded and extracted
17 as a preceding vehicle.

18 According to the embodiment of the present invention, since
19 the final own traveling path is calculated based upon the own traveling
20 path A (Xpra[i], i = 0 to 23) obtained from lane marker and side
21 wall data and the own traveling path B (Xprb[i], i = 0 to 23) derived
22 from the yaw rate of the own vehicle 1 and the own traveling path
23 D (Xprd[i], i = 0 to 23) calculated based on the trace of the preceding

1 vehicle, the own traveling path can be estimated accurately, stably
2 and securely.

3 Further, when the own traveling path C ($X_{prc}[i]$, $i = 0$
4 to 23) is calculated from the own traveling path A ($X_{pra}[i]$, $i =$
5 0 to 23) and the own traveling path B ($X_{prb}[i]$, $i = 0$ to 23) and
6 the own traveling path E ($X_{pre}[i]$, $i = 0$ to 23) is newly calculated
7 using the own traveling path C ($X_{prc}[i]$, $i = 0$ to 23) and the own
8 traveling path D ($X_{prd}[i]$, $i = 0$ to 23) produced based on the traveling
9 trace of the preceding vehicle, since an accurate judgment process
10 of ~~evacuation~~ a lane change is executed using the own traveling path
11 C ($X_{prc}[i]$, $i = 0$ to 23) and the own traveling path E ($X_{pre}[i]$, i
12 $= 0$ to 23) is synthesized according to the result of the judgment,
13 unnecessary calculations according to every behavior of the preceding
14 vehicle can be effectively prevented from being made and as a result
15 an accurate calculation of the own traveling path can be performed.

16 Further, the ON-OFF signal of the turn signal switch 9
17 and the value of the steering wheel rotation angle enable to obtain
18 the final own traveling path in a natural manner reflecting driver's
19 intention.

20 Furthermore, when the own traveling path E ($X_{pre}[i]$, i
21 $= 0$ to 23) is calculated using the own traveling path C ($X_{prc}[i]$,
22 $i = 0$ to 23) and the own traveling path D ($X_{prd}[i]$, $i = 0$ to 23)
23 derived from the traveling trace of the preceding vehicle, since

1 | the possibility of ~~evacuati~~ona lane change is judged not only
2 | according to the behavior of the preceding vehicle but also according
3 | to that of the solid object other than the preceding vehicle in the
4 | neighborhood of the preceding vehicle, the judgment of ~~evacuati~~ona
5 | lane change can be made more correctly.

6 | The entire contents of Japanese Patent Application No.
7 | Tokugan 2002-271905 filed September 18, 2002, is incorporated herein
8 | by reference.

9 | While the present invention has been disclosed in terms
10 | of the preferred embodiment in order to facilitate better
11 | understanding of the invention, it should be appreciated that the
12 | invention can be embodied in various ways without departing from
13 | the principle of the invention. Therefore, the invention should be
14 | understood to include all possible embodiments which can be embodied
15 | without departing from the principle of the invention set out in
16 | the appended claims.